GUIDELINES FOR REDUCING LOSSES OF LODGEPOLE PINE TO THE MOUNTAIN PINE BEETLE IN UNMANAGED STANDS IN THE ROCKY MOUNTAINS

Gene D. Amman, Mark D. McGregor,
Donn B. Cahill, and William H. Klein

USDA Forest Service General Technical Report INT-36
INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE

Cover Photo.--Mountain pine beetles have killed many trees in this lodgepole pine stand on the Targhee National Forest in southeast Idaho. Red trees that have retained most of their needles were killed in July or August of the preceding year. Gray trees and those with few red needles were killed during previous years.

USDA Forest Service
General Technical Report INT-36
June 1977

GUIDELINES FOR REDUCING LOSSES OF LODGEPOLE PINE TO THE MOUNTAIN PINE BEETLE IN UNMANAGED STANDS IN THE ROCKY MOUNTAINS

Gene D. Amman, Mark D. McGregor,

Donn B. Cahill, and William H. Klein

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Forest Service
U.S. Department of Agriculture
Ogden, Utah 84401

THE AUTHORS

Gene D. Amman is Principal Entomologist on the Population Dynamics of primary Bark Beetles research work unit in Ogden. Prior to joining the Intermountain Station in 1966, he was Entomologist with the Southeastern Forest Experiment Station in Asheville, N.C.

Mark D. McGregor is Entomologist, Forest Insect and Disease Management, State and Private Forestry, Missoula, Montana. Since 1967, he has been associated with the Missoula office and is now in charge of detection, evaluation, and control of bark beetle populations. Prior to his Missoula assignment, he served with the Intermountain Station and with the Insect Detection and Evaluation Section, Intermountain Region, both in Ogden.

Donn B. Cahill is Supervisory Entomologist, Forest Insect and Disease Management, State and Private Forestry, Denver, Colorado. He has been in charge of the Forest Insect Evaluation Section since 1967. Aside from his current assignment, he has served with the Equipment Development Center in Missoula and with the Insect Detection and Evaluation Section, Intermountain Region, Ogden.

William H. Klein is Survey Systems Specialist with the Methods Application Group, State and Private Forestry, Davis, California. Prior to assuming this assignment in 1976, he was in charge of the Forest Insect Detection and Evaluation Section, Intermountain Region, Ogden. Other assignments were with the Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, and the Eastern Region, Amherst, Mass.

CONTENTS

ABSTRACT

These guidelines are based on ecological relationships of the beetle and its host. They are applicable to unmanaged stands. In these stands, beetles show a strong preference for lodgepole pine of large diameter and 80 years of age or older. Stands at low elevations suffer the greatest losses to beetle infestation. At low elevations, climate is optimal for brood survival; the cool climate of high elevations has an adverse effect on survival of the beetle. These factors--tree diameter, tree age, and stand location--are used to predict stand risk to beetle infestation.

Measures can be taken to prevent or reduce losses to the beetle. Where timber production is the primary use of the land, large high-risk trees can be removed by partial cutting techniques. However, patch cutting or clearcutting should be used where most trees are in large-diameter classes and in stands where residual trees would not be numerically adequate nor physically vigorous should partial cutting techniques be used. Essentially, a "do nothing" policy is recommended where recreation values predominate or where noncommercial forests exist. Trees of high value in campgrounds, picnic areas, and near summer and permanent homesites can be protected with chemical sprays that prevent successful beetle infestation.

INTRODUCTION

The mountain pine beetle, *Dendroctonus ponderosae* Hopkins, presents the most serious threat to growing lodgepole pine, *Pinus contorta* var. *latifolia* Engelmann, for sawtimber and maintaining it for other purposes, including esthetics. Populations of the beetle periodically increase and kill most of the trees of large diameter in a forest before subsiding. The frequency of epidemics appears to be directly related to site quality, with stands on better sites growing into a susceptible state more rapidly than those on poor sites. Specifically, frequency and intensity of beetle epidemics are related to age, diameter distribution, phloem thickness distribution, and elevation and latitude of the stand. Although these are by no means all the factors that affect the mountain pine beetle, they are the most important identified so far as influencing beetle populations and subsequent tree losses.

The objectives of these guidelines are to describe habits of the beetle in lodgepole pine forest and to present some alternatives that land managers could use to reduce beetle-caused losses. There is no single answer to nor is there a sure cure for the mountain pine beetle problem because biological conditions vary and (most important) management objectives differ. At one time, direct attempts were undertaken to reduce beetle populations over large areas. These control efforts included treating felled and standing trees either by burning or by spraying with toxic chemicals. However, such methods have not effectively prevented subsequent tree losses in large outbreaks, primarily because the stand conditions that permit beetle populations to increase have not changed. Harvesting infested trees prior to brood emergence also has been tried to control beetle populations. Although this method was no more successful than the other methods, it at least utilized a resource that otherwise might have been lost. Our guidelines suggest alternatives that range from "do nothing" to clearcutting a stand, depending upon management's objectives.

To date, all research and development work with the mountain pine beetle and its host has been in unmanaged stands. The association of the beetle to its host in managed stands--stands that are manipulated to grow at or near optimum site capacity--is unknown. Lodgepole stands managed early and growing near optimum capacity will produce trees of large size early and, it is conceivable that under this influence, these fast-growing trees may be less vulnerable to the beetle and may incur less damage than trees of similar size in an unmanaged state. Research is lacking but badly needed in this concept. These guidelines then are applicable only to unmanaged lodgepole pine stands.

THE MOUNTAIN PINE BEETLE—LODGEPOLE PINE INTERACTION

Life Cycle of the Beetle

The mountain pine beetle usually has a single generation per year in lodgepole pine. New adults (fig. 1) emerge and infest living trees in July and August. Some years, emergence and infestation continue into September (fig. 2 and 3).

Vertical egg galleries are constructed in the inner bark and eggs are laid on both sides of the galleries (fig. 4). Larvae feed in the inner bark at right angles to the gallery and girdle the tree (fig. 5). Larvae overwinter and resume development in the spring. Other stages of the beetle are usually not hardy enough to survive winter temperatures. Development is usually completed by midsummer (fig. 6 and 7).

Figure 1.--Adult mountain pine beetles are dark brown to black and average about one-fifth of an inch in length.

Figure 2.--Pitch tubes on newly infested trees range in color from dark reddish orange to cream; they consist of pitch and particles of bark expelled from the egg gallery by beetles.

Figure 3.--Orange- to cream-colored particles of bark and wood in crevices and at the base indicate the tree has been infested and killed by beetles.

Considerable variation may occur in the life cycle depending upon local climatic conditions. For example, at low elevations, some beetles may complete a gallery, then emerge from the tree, and attack a second tree. At high elevations, attacks may occur late in the summer but because of cool temperatures most eggs may fail to hatch. Larvae from eggs that do hatch in the fall may require 2 years to become adults, emerge, and infest trees.

Parent beetles introduce several species of blue-stain fungi that invade the xylem. The fungi impede water conduction. Trees having well-developed blue stain tend to dry more rapidly during the fall of the year of attack, but remain more moist the following summer than trees having poorly developed blue stain (fig. 8). Moisture regulation by the fungi appears to be beneficial to developing beetles.

In Canada, resistance to beetle infestation has been equated to the tree's response to artificial infections of blue-stain fungi. Trees that respond to such infections with a copious flow of resin are considered more resistant than trees that respond with a light resin flow. Resistant trees tend to be those having thick phloem. When infested, such trees produce large numbers of beetles and are necessary to foster large epidemics of the beetle. Trees that are easily infected with blue-stain fungi are also easily killed by the beetle; since these are usually trees having thin phloem, they would be expected to produce few beetles.

The needles of infested trees change from green to a yellowish-green in the spring and finally to a bright orange by July (fig. 9) when the new brood is ready to emerge from the tree. Tree losses can be approximated rapidly by estimating the numbers of dead trees from aerial surveys.

Figure 4.--Vertical egg galleries are made in the bark; eggs are laid in the phloem on alternate sides of the gallery.

Figure 5.--The white- to cream-colored larvae usually feed at right angles to the egg gallery and girdle the tree. Average length of larvae is one-fourth inch.

Figure 6.--White- to cream-colored pupae are found in oval cells made by mature larvae. Average length of pupae is one-fifth inch.

Figure 7.--New adults are light brown to yellow (callow), turning almost black before emerging. Blue-stain fungi can be seen along the edge of the pupal cell containing the beetle on the left. Fungal spores are picked up by the adults when they feed prior to emerging and infesting a green tree. Average length of adults is one-fifth inch.

A

Figure 8.--Blue-staining fungi, carried into the bark by the beetles, discolor the sapwood.
A. Well-developed blue stain usually is uniformly distributed throughout the sapwood.
B. Poorly developed blue stain usually is unevenly distributed in the sapwood.

B

Figure 9.--Needles of infested trees usually change to a bright orange by July when the new brood is ready to emerge from the tree.

Diameter Distribution

The mountain pine beetle kills proportionately more large- than small-diameter trees. Losses range from a small proportion of trees 4 inches d.b.h. to a large proportion of trees over 10 inches d.b.h. (fig. 10). Beetles prefer the largest green trees left in the stand each year as the infestation progresses (fig. 11). After the beetles have killed most large-diameter trees, they infest some of the remaining small-diameter trees. Few beetles mature and emerge from these small trees; so the population declines. Beetle production is low in such trees because of the thin phloem and excessive drying of the tree.

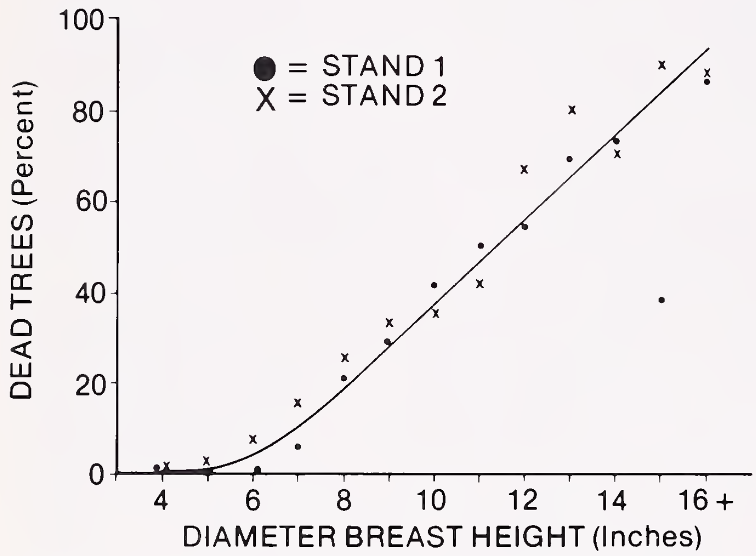

Figure 10.--The mountain pine beetle kills proportionately more large- than small-diameter trees during an infestation.

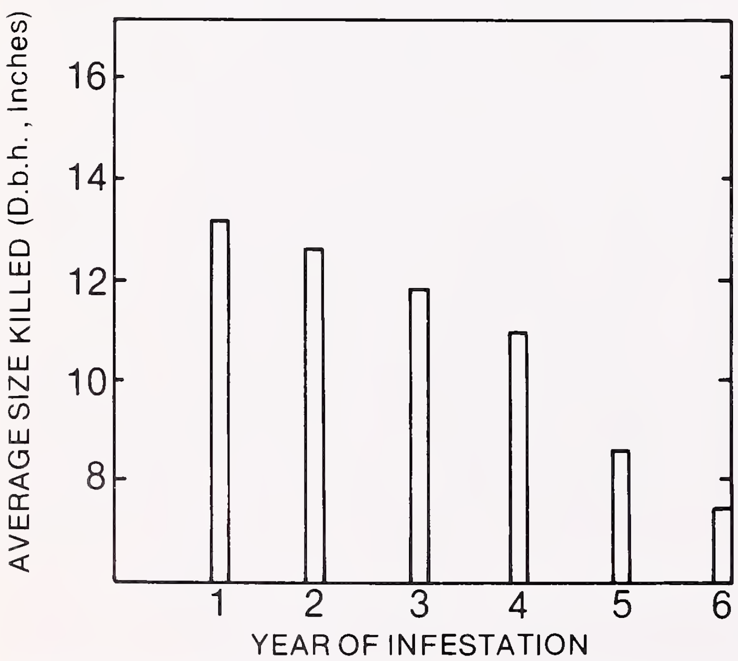

Figure 11.--The beetle usually kills the largest remaining green trees during each successive year of a major infestation.

Phloem Thickness

Phloem is the food of developing larvae. The amount of phloem is one of the most important factors determining the number of larvae that will complete development, become adults, emerge to attack new trees, and establish the next generation (fig. 12). On the average, the thicker the phloem (fig. 13), the greater will be the ratio of brood adults to parents that infested and killed the trees (fig. 14). This ratio will vary according to site quality and stand density as these factors affect phloem thickness.

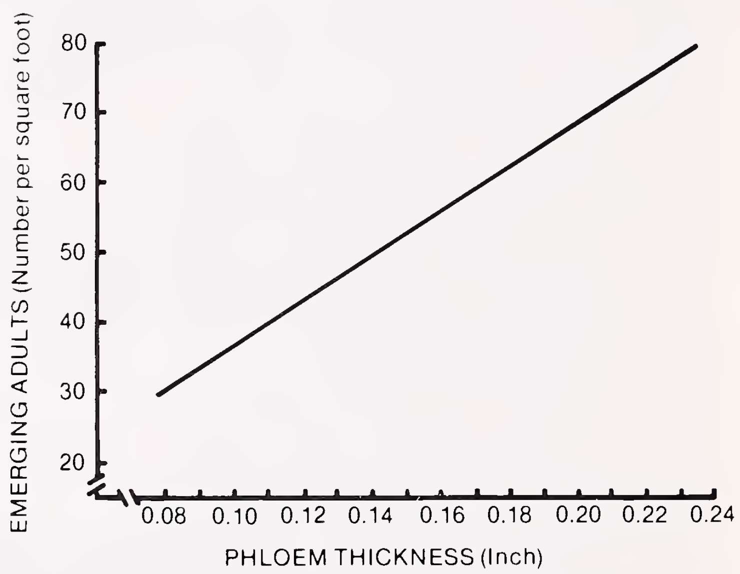

Figure 12.--Beetle production is directly related to thickness of the phloem layer of the infested tree.

Tree Age

Infestations of the beetle seldom develop in stands less than 60 years of age. This is partially due to trees being of small size and generally having thin phloem. The more resinous phloem frequently found in these trees may also be a contributing factor. Trees less than 60 years old, may be infested, but when they are, there is only slight danger that the

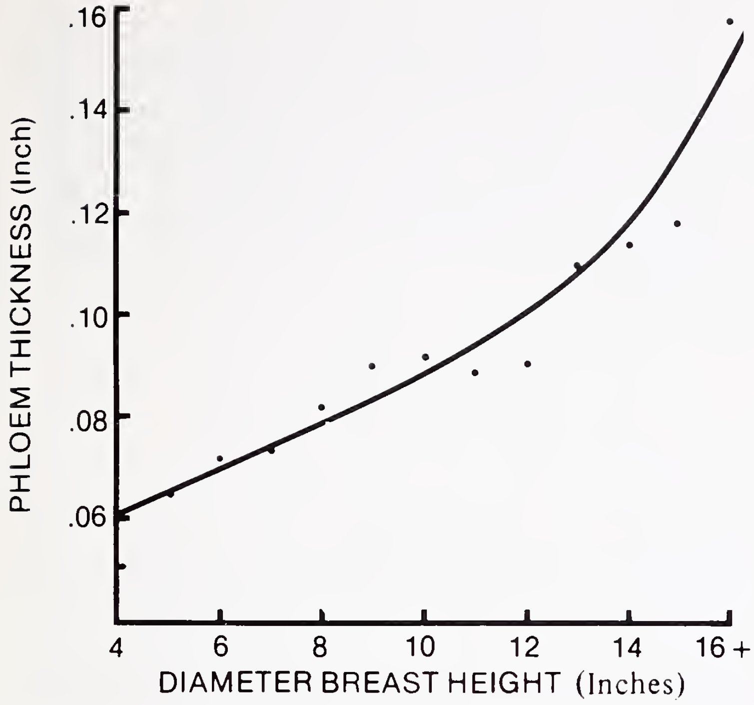

Figure 13.--Phloem is usually thicker in large-diameter trees than in small-diameter trees.

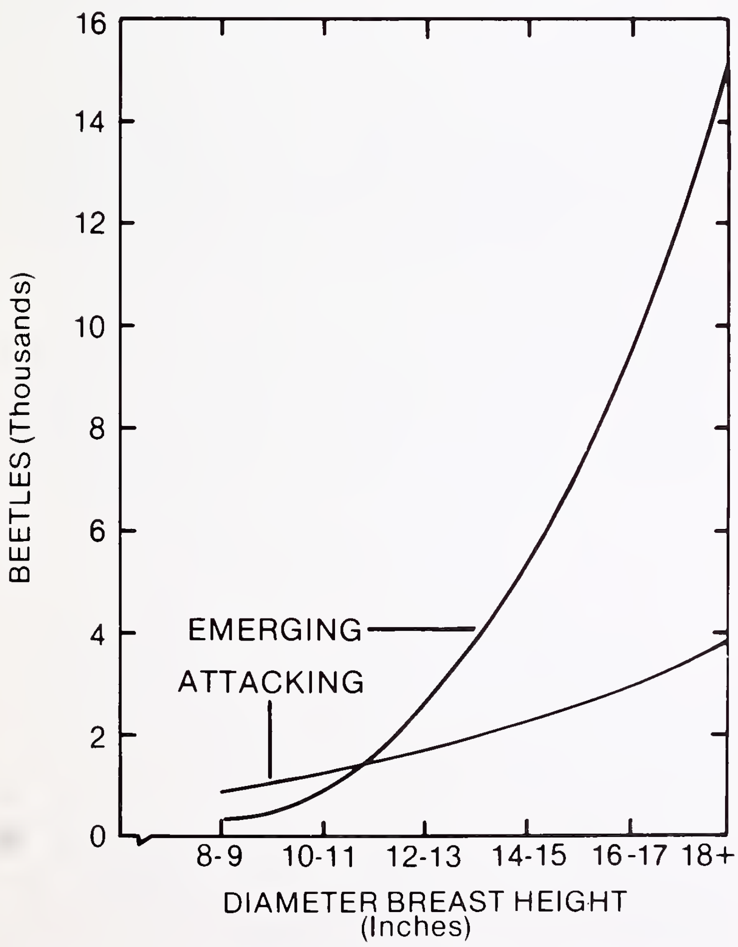

Figure 14.--Generally, the larger the tree, the larger is the ratio of brood adults (emerging) to parents attacking and killing the tree.

outbreak will develop to epidemic proportions. In the 60 to 80 year category, a larger proportion of the trees have reached diameters conducive to more severe and sustained beetle infestation. In these trees, phloem is thicker and its physical and perhaps chemical characteristics are better for beetle development. Stands more than 80 years of age present the greatest potential for beetle infestation. Stands having a large proportion of large-diameter trees with thick phloem are most likely to be infested and will suffer proportionately greater losses.

Stand Density

Density of stands affects growth rate of trees, and hence phloem thickness. Generally, stands having the lowest density have the greatest proportion of large-diameter trees with thick phloem (fig. 15). Because the average phloem thickness is greater, beetle production will be greater in trees of each diameter class in the more open stands (fig. 16). Consequently, losses in these stands will be proportionately greater than those in dense stands.

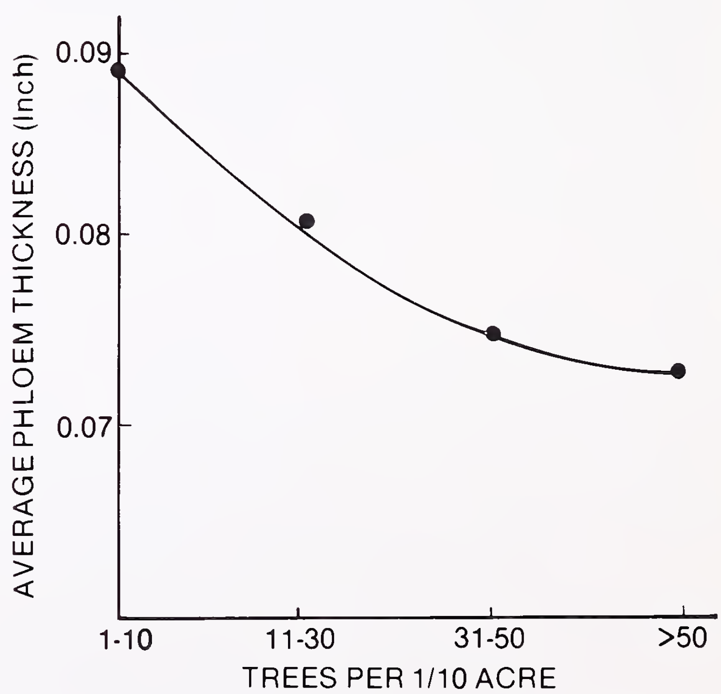

Figure 15.--Trees in dense stands have thinner phloem than those in open stands.

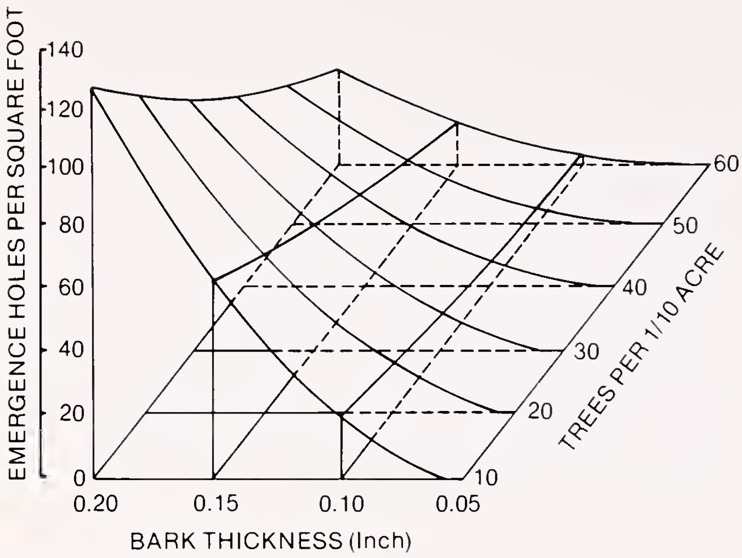

Figure 16.--Beetle production is less in trees of dense stands. Such trees have thinner bark and lower average phloem thickness. Generally, as total bark thickness increases, phloem thickness also increases.

Elevation and Latitude

With increased elevation, tree losses to the mountain pine beetle decline (fig. 17). The cool climate of high elevations so slows beetle development that 2 years may be required for most of the population to complete a single generation. During these long developmental periods, beetle mortality is greater, thus reducing populations more than when a generation is completed in a single year. Slowing of development frequently results in beetles emerging in late summer. Because of the late establishment of egg galleries many eggs fail to hatch before winter. These eggs are killed by cold temperatures. In assessing the effect of temperature on the beetle and its potential to kill trees, both elevation and latitude of the lodgepole pine stand must be considered. Hopkins' Bioclimatic Law[1] has general application.

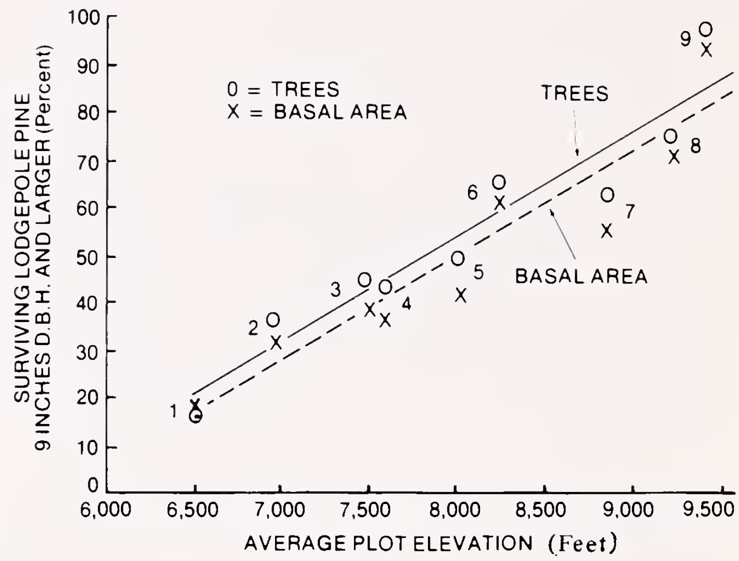

Figure 17.--Tree survival from beetle infestation is directly related to elevation. These data obtained at 44° N. lat., 110° W. long.

[1]Hopkins' Bioclimatic Law states that variation in seasonal development and habits of plants and animals at different geographical positions within the range of their distribution is at the rate of 4 days for each degree of latitude, 5 degrees of longitude, or 400 feet of elevation.

PREDICTING STAND SUSCEPTIBILITY

Elevation and latitude, age, and average d.b.h. are used in these guidelines to predict stand susceptibility. Phloem has not been included as one of the variables even though it is of primary importance in beetle production at low to middle elevations. However, phloem thickness is generally related to d.b.h. in any given stand of trees and d.b.h. is easier to measure.

In order to be susceptible to a beetle epidemic, a lodgepole pine stand must be located at an elevation and latitude where climate is favorable to the beetle. A general model for determining if a stand lies within a zone of potentially heavy, moderate, or light risk to beetle infestation is presented in figure 18. Even if a lodgepole pine is in an elevation and latitude zone of potentially heavy beetle damage, the stand must meet other requirements for the beetle to be successful. In general, stand age must be 80 years or more, and the average d.b.h. of a stand for trees 5 inches and larger must exceed 8 inches.

By multiplying the following risk factors (1 = low; 2 = moderate; 3 = high) for elevation and latitude, average age, and average d.b.h., the stand's susceptibility classification is obtained; low = 1 to 9; moderate = 12 to 18; high = 27.

Elevation-latitude		*Average age (Years)*		*Average d.b.h. (Inches)*	
High	(1)	<60	(1)	<7	(1)
Moderate	(2)	60-80	(2)	7-8	(2)
Low	(3)	>80	(3)	>8	(3)

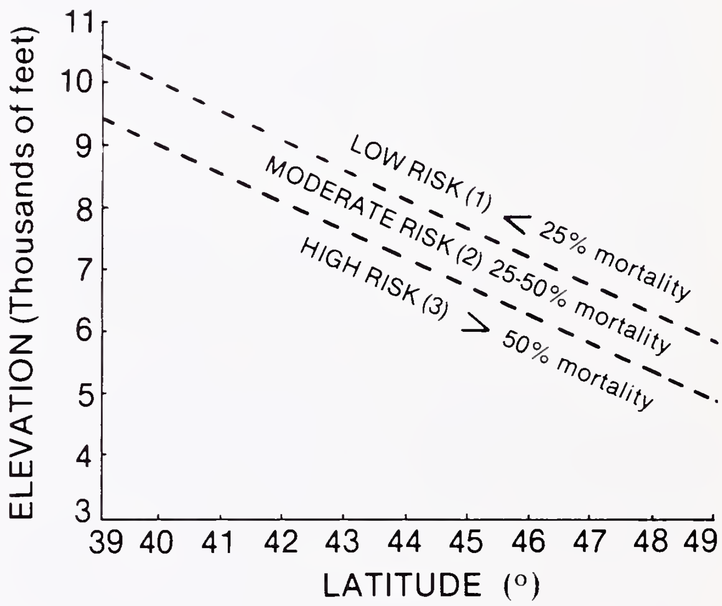

Figure 18.--Risk of mountain pine beetle infestation in lodgepole pine can be defined by zones of elevation and latitude. Percent mortality is for trees 8.5 inches d.b.h. and larger.

For example, when the risk factors for a high elevation stand (risk of 1) more than 80 years old (risk of 3) with an average d.b.h. of 9 inches (risk of 3) are multiplied (1×3×3=9), the stand has a low index for beetle infestation and tree loss because of its elevational location. But, a stand at a low elevation (3) with an average age of 80 (3) and an average d.b.h. of 8.5 (3) has a high index (3×3×3=27) for infestation and subsequent tree loss.

The categories for elevation and latitude, average age, and average d.b.h. have been broadly defined. With additional surveys of infested stands, damage categories may be more precise and perhaps additional ones added.

REDUCING LOSSES TO THE BEETLE

Stands that show a high probability of infestation and subsequent loss to the beetle can be dealt with in several ways, depending upon land-use objectives.

Where Timber Values Are Primary

1. Recognizing that the beetle concentrates heavily on trees of large diameter, continuous lodgepole pine forests can be broken up into small patch cuts, which will result in different age and size classes and so reduce the area likely to be infested at any one time. Then, when a patch reaches high-risk conditions, all trees on the patch can be harvested immediately.

By using a model to predict growth of lodgepole pine in any given stand, the manager can determine when stands of different ages will reach age and size distributions conducive to beetle epidemics. Plans for harvest can be made many years in advance.

2. Since the beetle shows preference for trees of large diameter, partial cuts directed at such trees will greatly reduce infestation potential (fig. 19). Removal of most trees 8 inches d.b.h. and larger would "beetleproof"

Figure 19.--Removal of large-diameter trees will reduce the infestation index and, consequently, tree losses to the mountain pine beetle.

most stands. However, when partial cuts are to be used, the residual stand should have enough physically vigorous trees to maintain stocking and stand productivity.

Partial cutting may not be the best method to handle beetle problems in understocked stands. In such stands, a large proportion of trees in diameter classes of less than 8 inches may have thick phloem. In those trees, beetle production may continue to be high enough to maintain the infestation, resulting in considerable tree mortality. Clearcutting and regenerating the stand may be the best method of handling high-risk understocked stands.

Problems associated with partial cuts in some stands of lodgepole pine necessitate clearcuts. Windfall in stands opened up by partial cuts can be of particular concern on certain sites. In addition, dwarf mistletoe, *Arceuthobium americanum* Nutt. ex Engelm., is most damaging in stands that have been partially cut, unless the stand is only lightly infected.

3. Harvesting trees before they reach sizes conducive to beetle outbreaks would be an effective method of preventing losses to the beetle where there are markets for material of small diameter. For example, in certain high-risk areas, the manager may elect to grow small trees that meet pole and mine timber requirements.

4. Another management alternative for stands that are particularly susceptible to beetle damage is to favor nonhost trees such as Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco. In mixed species forests, the presence of nonhost trees will result in greater residual stocking should an epidemic occur. However, the beetle infests lodgepole pine in mixed species forests just as readily as in pure forests. In addition, the manager also must realize that if he elects to convert lodgepole pine forests to other species, he can expect losses by other insects--the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins, if Douglas-fir is favored, and the larch casebearer, *Coleophora laricella* (Hubner), if western larch, *Larix occidentalis* Nutt., is favored However, entomologists generally agree that most insects would prove easier to cope with than the mountain pine beetle, particularly if blocks of nonhost species of trees are interspersed among blocks of lodgepole pine. Then, when any insect infestation occurs, less acreage of host type would be affected.

Where Nontimber Values Are Primary

Forests that are committed to recreation, such as National and State Parks, Wilderness Areas, and other forested land not included in the timber-growing base, may not require action against the beetle. In seral lodgepole pine forest protected from fire, the proportion of other tree species can be expected to increase with each beetle infestation, until succession is complete and both lodgepole pine and the beetle are eliminated from the stand (fig. 20).

Conversion of noncommercial lodgepole pine forests to nonhost species of trees will eliminate the possibility of beetle populations building up and moving from noncommercial to adjacent commercial forested land. In the absence of fire, conversion of lodgepole pine forests can be expected to occur naturally where lodgepole pine is seral, being succeeded by Douglas-fir at lower elevations and subalpine fir, *Abies lasiocarpa* (Hook.) Nutt., and Engelmann spruce, *Picea engelmannii* Parry, at higher elevations. If fire occurs prior to completion of succession, some of these stands will revert to lodgepole pine and another cycle of mountain pine beetle infestations.

In stands where lodgepole pine is climax, periodical infestations of the beetle can be expected as trees in a portion of the stand develop large diameters and thick phloem, conditions needed by the beetle. Openings created in the forest when dominant and codominant trees are killed by beetles are seeded by lodgepole, thus forming an uneven-aged, multistoried forest.

In addition to the loss of most large-diameter trees, allowing infestations to run their natural courses will have some positive as well as other negative effects.

Some negative effects.--After an infestation, large numbers of dead trees fall across roads, trails, fences, powerlines, and recrea-

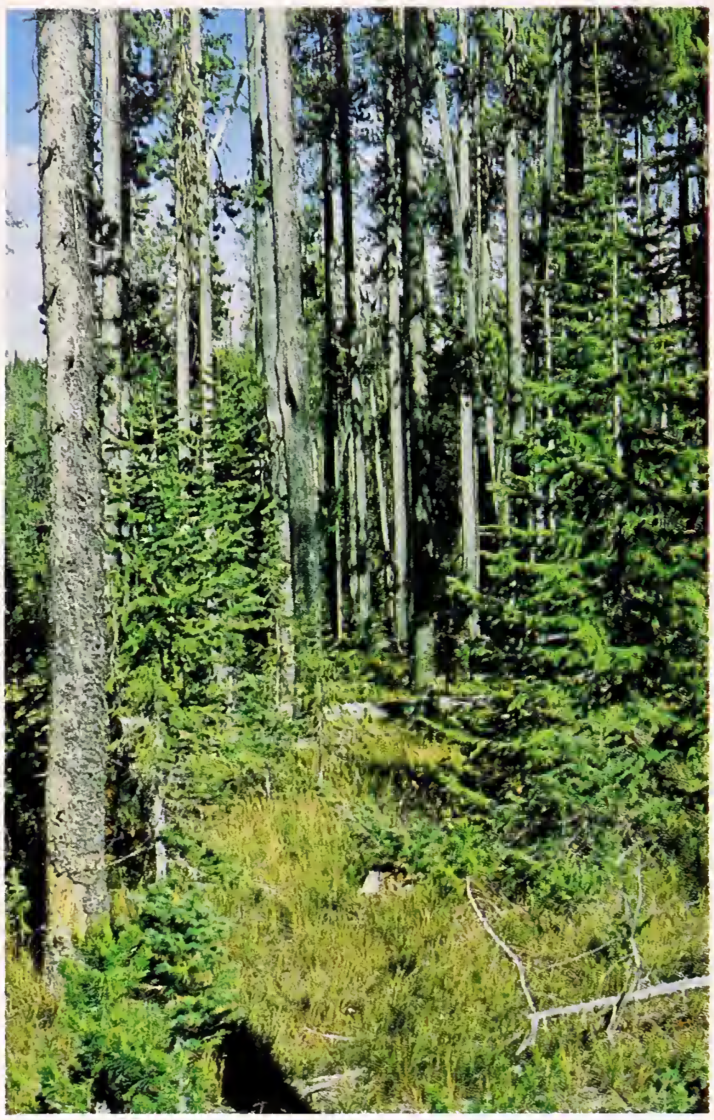

Figure 20.--A mixed lodgepole pine/spruce-fir forest: Natural conversion to nonhost species on land not included in the timber-growing base will eliminate lodgepole pine and the mountain pine beetle.

tional facilities unless they are removed. In addition, there is potential danger from falling trees to hikers, campers, and others using the forests. Fallen trees may limit access of both wild and domesticated animals. Increased fuel loads result in hotter, more destructive fire when fire does occur (fig. 21).

Some positive effects.[2]--Within the 1 to 10-year period following the infestation, snags will provide perches and nesting sites for some raptors and cavity-nesting birds. Fallen trees provide nesting sites and protection for ground-dwelling birds and bedding and cover for black bears, grizzly bears, and squirrels. Shrubs and understory that develop in openings created by loss of trees provide browse, berries, and cover for nesting and foraging birds, bears, and ungulates. The herbaceous understory provides additional forage for both domestic and wild ungulates. Increased water production can also be expected during these 10 years.

Eleven to 30 years after infestation, snags become fewer but downfall increases as decay of the roots and lower boles of dead trees increases. Foraging by bears for grubs and mushrooms increases. Cover and food provided by the understory shrubs peak and begin to decline as dominant pines compete for space. Bird species composition is more diverse. Some understory shrubs begin to succumb to competition from saplings.

After 30 years, snags become uncommon and decay of downfall reduces the problem of access by large ungulates. Rodent cover and logs containing grubs for bears diminish. Shrubs and herbaceous understory are reduced as the canopy of the tree overstory closes. Closing of the canopy results in improved squirrel and ungulate cover.

---

[2]Information on effects of mountain pine beetle infestations on wildlife was furnished by Roger S. Bumstead, Wildlife Specialist, Wildlife and Fisheries Staff Unit, Forest Service, Missoula, Montana 59801.

Figure 21.--Fallen trees, mostly lodgepole pines killed during several infestations by the mountain pine beetle, limit access and increase fuel loads.

Where Individual Trees Have High Value

Trees in picnic areas, campgrounds, around visitor centers, and summer and permanent homesites have much higher value than trees in the forest situation. Chemical sprays offer promise for protection of such trees (fig. 22). A single application before flight and attack by beetles has prevented attacks for 1 year and, in some instances, through a second year. The use of such chemicals will vary form State to State. Information on their availability can be obtained from the Forest Insect and Disease Management unit at any of the western Regional Offices or the Washington Office of the Forest Service.

Managers of high-use recreation areas should also consider planting trees of different species where lodgepole pine trees have been killed. Thus, shade and esthetics will be preserved as other lodgepole pines die or are killed by beetles.

Figure 22.--Trees of high value can be protected by chemical sprays applied before beetles make their attack. (Photo courtesy of Lawrence E. Stipe.)

BIBLIOGRAPHY

Alexander, Robert R.
1975. Partial cutting in old-growth lodgepole pine. USDA For. Serv. Res. Pap. RM-136, 17 p. Rocky Mt. For. and Range Exp. Stn., Ft. Collins, Colo.

Amman, Gene D.
1972. Mountain pine beetle brood production in relation to thickness of lodgepole pine phloem. J. Econ. Entomol. 65:138-140.

Amman, Gene D.
1973. Population changes of the mountain pine beetle in relation to elevation. Environ. Entomol. 2:541-547.

Amman, Gene D., and Bruce H. Baker.
1972. Mountain pine beetle influence on lodgepole pine stand structure. J. For. 70:204-209.

Amman, Gene D., Bruce H. Baker, and Lawrence E. Stipe.
1973. Lodgepole pine losses to mountain pine beetle related to elevation. USDA For. Serv. Res. Note INT-171, 8 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Bethlahmy, Nedavia.
1974. More streamflow after a bark beetle epidemic. J. Hydrol. 23:185-189.

Cole, Dennis M.
1973. Estimation of phloem thickness in lodgepole pine. USDA For. Serv. Res. Pap. INT-148, 10 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Cole, Dennis M., and Albert R. Stage.
1972. Estimating future diameters of lodgepole pine trees. USDA For. Serv. Res. Pap. INT-131, 20 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Cole, Walter E., and Gene D. Amman.
1969. Mountain pine beetle infestations in relation to lodgepole pine diameters. USDA For. Serv. Res. Note INT-95, 7 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Cole, Walter E., Gene D. Amman, and Chester E. Jensen.
1976. Mathematical models for the mountain pine beetle-lodgepole pine interaction. Environ. Entomol. 5:11-19.

Cole, Walter E., and Donn B. Cahill.
1976. Cutting strategies can reduce probabilities of mountain pine beetle epidemics in lodgepole pine. J. For. 74:294-297.

Dooling, Oscar J., and Donald H. Brown.
1976. Guidelines for dwarf mistletoe control in lodgepole pine in Northern and Central Rocky Mountains. USDA For. Serv., For. Environ. Prot. Rep. 76-14, 9 p. Missoula, Montana.

Evenden, James C., and A. L. Gibson.
1940. A destructive infestation in lodgepole pine stand by the mountain pine beetle. J. For. 38:271-275.

Hamel, D. R., and M. D. McGregor.
1976. Evaluation of mountain pine beetle infestations; Lap, Cool, Lang, and Caribou drainages, Yaak Ranger District, Kootenai National Forest, Montana. USDA For. Serv., For. Environ. Prot. Rep. 76-6, 10 p., Missoula, Montana.

Hamel, D. R., and M. D. McGregor.
1976. Harvesting strategies for management of mountain pine beetle infestations in lodgepole pine, Montana, Progress Report. USDA For. Serv., For. Environ. Prot. Rep. 76-3, 7 p., Missoula, Montana.

Hatch, Charles R.
1967. Effects of partial cutting in overmature lodgepole pine. USDA For. Serv. Res. Note INT-66, 7 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Hawksworth, F. G.
1958. Rate of spread and intensification of dwarf mistletoe in young lodgepole pine stands. J. For. 56:404-407.

Hawksworth, F. G.
1973. Dwarf mistletoe and its role in lodgepole pine ecosystems. *In:* Management of lodgepole pine ecosystems Symp. Proc., p. 342-358. David M. Baumgartner, ed. Wash. State Univ., Coop. Ext. Serv., Pullman, Wash.

Hopkins, Andrew D.
1919. The bioclimatic law as applied to entomological research. Sci. Mon. 8:496-513.

Hopping, George R., and Geoffrey Beall.
1948. The relation of diameter of lodgepole pine to incidence of attack by the bark beetle *(Dendroctonus monticolae* Hopk.*)*. For. Chron. 24:141-145.

Klein, William H.
1973. Beetle-killed pine estimates. Photogramm. Eng. 39:385-388.

Klein, William H.
1976. Preliminary report of a survey to measure the impact of the mountain pine beetle in a lodgepole pine forest. USDA For. Serv., Intermt. Reg., 7 p. Ogden, Utah.

Klein, William H., Lawrence E. Stipe, and Lyn V. Frandsen.
1972. How damaging is a mountain pine beetle infestation? A case study. 7 p. U.S. For. Serv., Branch For. Insect and Dis. Prev. and Control, Ogden, Utah.

McGregor, M. D., D. R. Hamel, and R. C. Lood.
1976. Evaluation of mountain pine beetle infestation, Gallatin Ranger District, Gallatin National Forest, Montana, 1975. USDA For. Serv., For. Environ. Prot. Rep. 76-5, 11 p., Missoula, Montana.

McGregor, M. D., D. R. Hamel, R. C. Lood, and H. E. Meyer.
1975. Status of mountain pine beetle infestations in Glacier National Park, Montana. USDA For. Serv., For. Environ. Prot. Rep. 75-10, 7 p., Missoula, Montana.

Myers, Clifford A., Frank G. Hawksworth, and James L. Stewart.
1971. Simulating yields of managed, dwarf mistletoe-infested lodgepole pine stands. USDA For. Serv. Res. Pap. RM-72, 15 p. Rocky Mt. For. and Range Exp. Stn., Ft. Collins, Colo.

Parker, Douglas L.
1973. Trend of a mountain pine beetle outbreak. J. For. 71:698-700.

Reid, R. W.
1961. Moisture changes in lodgepole pine before and after attack by the mountain pine beetle. For. Chron. 37:368-403.

Reid, R. W.
1963. Biology of the mountain pine beetle, *Dendroctonus monticolae Hopkins,* in the east Kootenay region of British Columbia. III. Interaction between the beetle and its host, with emphasis on brood mortality and survival. Can. Entomol. 95:225-238.

Roe, Arthur L., and Gene D. Amman.
1970. The mountain pine beetle in lodgepole pine forests. USDA For. Serv. Res. Pap. INT-71, 23 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Safranyik, L., D. M. Shrimpton, and H. S. Whitney.
1974. Management of lodgepole pine to reduce losses from the mountain pine beetle. Can. Dep. Environ., For. Serv., Pac. For. Res. Cent. Tech. Rep. 1, 24 p.

Safranyik, L., D. M. Shrimpton, and H. S. Whitney.
1975. An interpretation of the interaction between lodgepole pine, the mountain pine beetle and its associated blue stain fungi in Western Canada. *In:* Management of lodgepole pine ecosystems, Symp. Proc., p. 406-428. David M. Baumgartner, ed. Wash. State Univ. Coop. Ext. Serv., Pullman, Wash.

Shepherd, R. F.
1966. Factors influencing the orientation and rate of activity of *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae). Can. Entomol. 98:507-518.

Shrimpton, D. M.
1973. Age- and size-related response of lodgepole pine to inoculation with *Europhium clavigerum*. Can. J. Bot. 51:1155-1160.

Smith, R. H., G. C. Trostle, and W. F. McCambridge.
In press. Protective spray tests on three species of bark beetles. J. Econ. Entomol.

Stage, Albert R.
1973. Prognosis model for stand development. USDA For. Serv. Res. Pap. INT-137, 32 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Field programs and research work units are maintained in:

- Billings, Montana
- Boise, Idaho
- Bozeman, Montana (in cooperation with Montana State University)
- Logan, Utah (in cooperation with Utah State University)
- Missoula, Montana (in cooperation with University of Montana)
- Moscow, Idaho (in cooperation with the University of Idaho)
- Provo, Utah (in cooperation with Brigham Young University)
- Reno, Nevada (in cooperation with the University of Nevada)

☆ U.S. GOVERNMENT PRINTING OFFICE: 1979 — 679-304

Amman, Gene D., Mark D. McGregor, Donn B. Cahill, and William H. Klein.
1977. Guidelines for reducing losses of lodgepole pine to the mountain pine beetle in unmanaged stands in the Rocky Mountains. USDA For. Serv. Gen. Tech. Rep. INT-36, 19 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Risk of lodgepole pine stands being infested by the mountain pine beetle is determined by average tree diameter, average tree age, and location by elevation and latitude. Methods to reduce losses to the beetle will depend upon land-use objectives. Where the use is timber production, large trees, which have a high risk of infestation, can be removed by either partial or patch cutting. Noncommercial forests do not require action against the beetle. Trees of high value in campgrounds, picnic areas, and near homesites can be protected from infestation by chemical sprays.

KEYWORDS: *Dendroctonus ponderosae, Pinus contorta,* control, bark beetle.

Amman, Gene D., Mark D. McGregor, Donn B. Cahill, and William H. Klein.
1977. Guidelines for reducing losses of lodgepole pine to the mountain pine beetle in unmanaged stands in the Rocky Mountains. USDA For. Serv. Gen. Tech. Rep. INT-36, 19 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Risk of lodgepole pine stands being infested by the mountain pine beetle is determined by average tree diameter, average tree age, and location by elevation and latitude. Methods to reduce losses to the beetle will depend upon land-use objectives. Where the use is timber production, large trees, which have a high risk of infestation, can be removed by either partial or patch cutting. Noncommercial forests do not require action against the beetle. Trees of high value in campgrounds, picnic areas, and near homesites can be protected from infestation by chemical sprays.

KEYWORDS: *Dendroctonus ponderosae, Pinus contorta,* control, bark beetle.

NATIONAL FOREST SYSTEM
COOPERATIVE FORESTRY
FOREST SERVICE
U S
DEPARTMENT OF AGRICULTURE
FORESTRY RESEARCH